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Dc Motor Control Using Ziegler Nichols and Genetic Algorithm Technique

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ABSTRACT : The aim of this paper is to study the Position control of DC motor using Ziegler and Nichols and Genetic Algorithm. The proposed method compares two kinds of tuning methods. One is the controller design by the genetic algorithm, second is the controller design by the Ziegler and Nichols method. It was found that the proposed PID parameters adjustment by the genetic algorithm is better than the Ziegler & Nichols' method. This proposed method could be applied to the higher order system also.

Keywords: DC Shunt Motor; Ziegler Nichols Technique; Genetic Algorithm;

I. INTRODUCTION

DC drive systems are often used in many industrial applications such as robotics, actuation and manipulators. In the first two, a wide range of position control is required. Tuning method for PID controller is very important for the process industries. Proportional Integral Derivative (PID) controllers have the advantage of simple structure, good stability, and high reliability [1]. Accordingly, PID controllers are widely used to control system outputs, especially for systems with accurate mathematical models. The key issue for PID controllers is the accurate and efficient tuning of parameters. In practice, controlled systems usually have some features, such as nonlinearity, time–variability, and time delay, which make controller parameter tuning more complex. Moreover, in some cases, system parameters and even system structure can vary with time and environment. As a result, the traditional PID parameter tuning methods are not suitable for these difficult calculations.

As a popular optimization algorithm, the Genetic Algorithm had been widely used to turn PID parameters. The PID controllers based on Genetic Algorithm have good performance and has been applied in practice.

The aim of this paper is to design a DC motor control using Ziegler and Nichols and Genetic Algorithm. Genetic Algorithm or in short GA is a stochastic algorithm based on principles of natural selection and genetics. Genetic Algorithms (GAs) are a stochastic global search method that mimics the process of natural evolution. Genetic Algorithms have been shown to be capable of locating high performance areas in complex domains without experiencing the difficulties associated with high dimensionality or false optima as may occur with normal PID techniques. Using genetic algorithms to perform the tuning of the controller will result in the optimum controller being evaluated for the system every time.

In order to solve this problem a PID controller under Genetic Algorithm with self–tuning is applied, which will perform high efficiency position control. The efficiency of Control Algorithm is presented through a simulation and compared with the quality of PID controller.

II. DESIGN REQUIREMENTS

First, our un–compensated motor can only rotate with a step input. Since the most basic requirement of a motor is that it should rotate at the desired Position, the steady–state error of the motor Position should be smaller than 1%. The other performance requirement is that the motor will accelerate to its steady–state Position quickly after it's turned on. In this case, we want it to have a settling time of 2 seconds. Since a Position faster than the requirement may damage the equipment, we also want to have an overshoot smaller than 5% [4]. If we simulate the reference input (R) by a unit step input, then the motor output should have:

- settling time less than 2 seconds
- overshoot less than 5%
- steady–state error less than 1%.

III. MATHEMATICAL MODELING OF DC MOTOR

We consider a DC shunt motors as is shown in Fig. 1. DC shunt motors have the field coil in parallel (shunt) with the armature. The current in the field coil and the armature are independent of one another. As a result, these motors have excellent position control. Hence DC shunt motors are typically used applications that require five or more horse power.

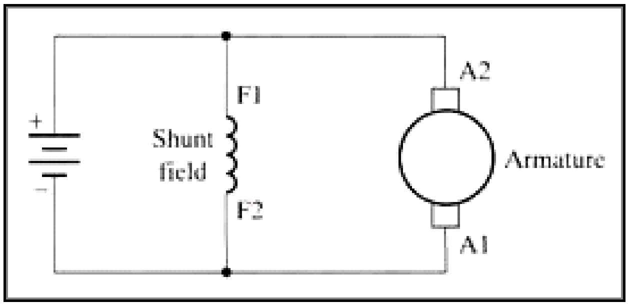

Fig. 1. DC shunt Motor.

The input voltage V is applied to the field winding which has a resistance and inductance of R and L respectively. The armature current supplied to the armature is kept constant and thus the motor shaft is controlled by the input voltage. The field current produces a flux in the machine which in turn produces a torque at the motor shaft. The moment of inertia and the coefficient of viscous friction at the motor shaft are J and B respectively. The angular position of motor shaft being is θm and the corresponding angular velocity is ωm [1].The parameters of dc motor shown in table 1

Table 1: Parameters of DC Shunt Motor.

Parameter	Value
Moment of inertia J	0.022Kg–m2/rad
Damping coefficient b	0.5*10^–3 N–m/(rad/sec).
Torque constant Kt	0.06 N.m/A
Electromotive force constant Kb	1.0 V.s/rad
Electrical resistance R	2.45 ohms
Electrical inductance L	0.035 Henry

A. System Equations

If armature current is kept constant the relationship between the developed motor torque Tm and the field current is given by

$$T_m \propto i_f \quad \text{…(1.1)}$$

$$T_m = K f i_f \quad \text{…(1.2)}$$

The equations describing the dynamic behavior of the DC motor are given by the following equations;

$$V = Ri + L\left(\frac{di}{dt}\right) + eb \quad \text{…(1.3)}$$

$$T_m = K_t i_a(t) \quad \text{…(1.4)}$$

$$T_m = J\frac{d^2\theta(t)}{dt^2} + B\frac{d\theta(t)}{dt} \quad \text{…(1.5)}$$

$$eb = eb(t) = Kb\frac{d\theta(t)}{dt} \quad \text{…(1.6)}$$

Simplification and taking the ratio of θ(s)/v(s) gives the transfer function as shown below,

θ(s)/v(s) = Kb/[J La S ^ 3 + (Ra J + B La) S ^ 2 + (Kb ^ 2 + Ra B) S] ...(1.7)

θ(s)/v(s) = 1.0/(.00077 s ^ 3 0.0539s ^ 2 + 1.441s) ...(1.8)

IV ZIEGLER NICHOLS TECHNIQUE

The block diagram shown in Fig. 2 illustrates a closed–loop system with a PID controller in the direct path, which is the usual connection. The system's output should follow as closely as possible the reference signal (set point) [1, 2].

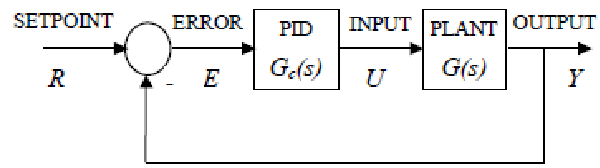

Fig. 2. PID Control.

The tuning of a PID controller consists of selecting gains K_p, K_i and K_d so that performance specifications are satisfied. By employing Ziegler– Nichols's method for PID tuning [1, 3] those gains are obtained through experiments with the process under control. Controller tuning involves the selection of the best values of K_p, K_i and K_d. PID gain values is given below Table 2, 3.

Table 2: Recommended PID Value Setting.

Types of controller	K_p	T_i	T_d
P	0.5 Ker	0	0
PI	0.45Ker	(1/1.2) Per	0
PID	0.6 Ker	0.5 Per	0.125 Per

Table 3: PID Values.

K_p	K_i	K_d
18	6.3223	12.811

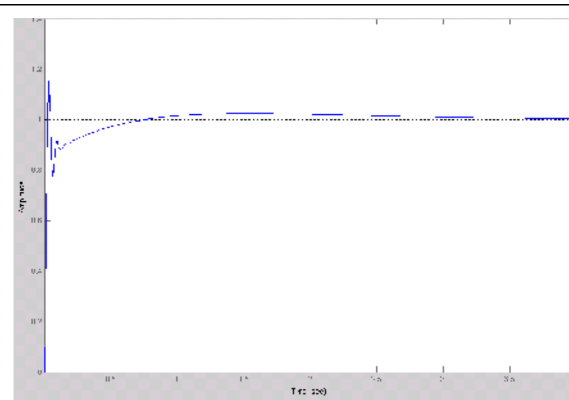

Fig. 3. Closed–loop step responses for DC shunt motor.

V. TUNING OF PID CONTROLLER USING GENETIC ALGORITHM APPROACH

Genetic algorithm (GA) is a heuristic mimicking the natural evolution process and is routinely used to generate useful solutions to optimization problems. In this paper the genetic algorithm is used to derive the PID controller parameters. In GA [7, 8].

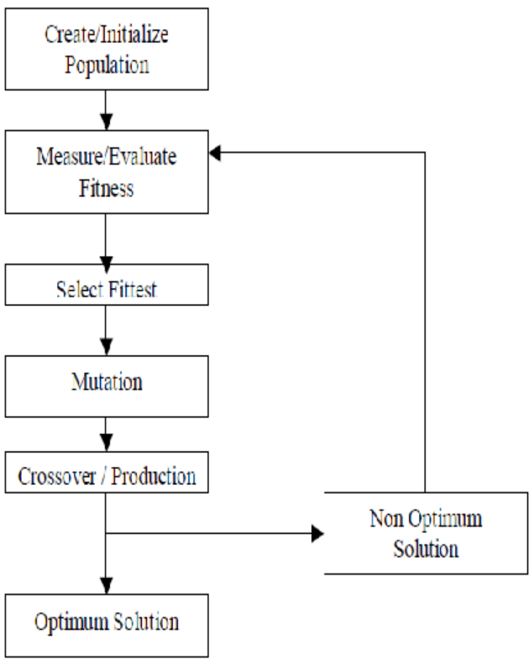

Fig. 4. Genetic algorithm process flowchart.

a population of strings called chromosomes encodes the possible solutions of an optimization problem and evolves for a better solution by process of reproduction The process of evolution starts from a population of randomly generated individuals. Optimization is achieved in generations where in each generation, the fitness function evaluates each individual in the population and multiple individuals are selected stochastically based on their fitness. These selected individuals are modified to form a new population. The algorithm terminates when either a maximum number of generations has been produced, or a satisfactory fitness level has been reached for the population [6, 11]. The various steps in GA based optimization are detailed below.

A. Initialization

The initial population few individual solutions are generated. The population is generated randomly, covering the entire range of possible solutions.

B. Selection

In each generation, individual solutions are selected by evaluating the fitness function and the fitter solutions have a higher probability of selection

C. Reproduction

Next set of population for the successive generation is generated by a process called reproduction and involves crossover (recombination) and mutation. These results in a new set of population derived from the fitter solutions of the previous population. Generally the average fitness of the population is heightened as compared to the population of the previous population.

D. Termination

The process of optimization is halted once a termination condition is achieved. The termination condition can be either the number of generations or the solution satisfying an optimum criterion [5].

VI. IMPLEMENTATION OF GA CONTROLLER

GA can be applied to the tuning of PID position controller gains to ensure optimal control performance at nominal operating conditions [9, 10]. The Genetic Algorithm parameters chosen for the tuning purpose are shown below table 4.

Table 4: Parameters of GA.

GA property	Value/Method
Population Size	80
fitness function	MSE
Selection Method	Geometric Selection
Crossover Method	Arithmetic
Number of crossover points	3
Mutation Method	Uniform Mutation
Mutation Probability	0.01

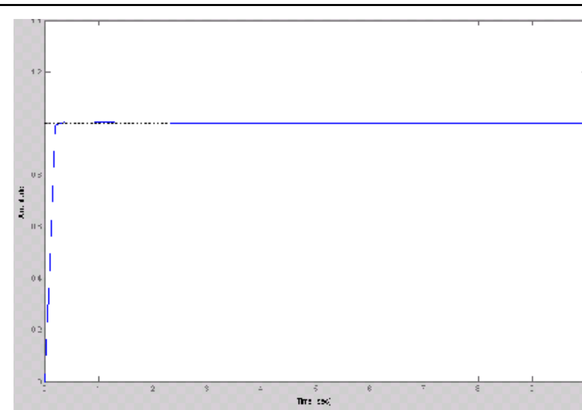

Fig. 5. Position control using Genetic Algorithm.

VII. ANALYSIS OF RESULT

All the conventional methods of controller tuning lead to a large settling time, overshoot, rise time and steady state error of the controlled system. Hence a Soft computing techniques is introduces into the control loop. GA, based tuning methods have proved their excellence in giving better results by improving the steady state characteristics and performance indices. The output response shown in Fig. 6. Table 5.

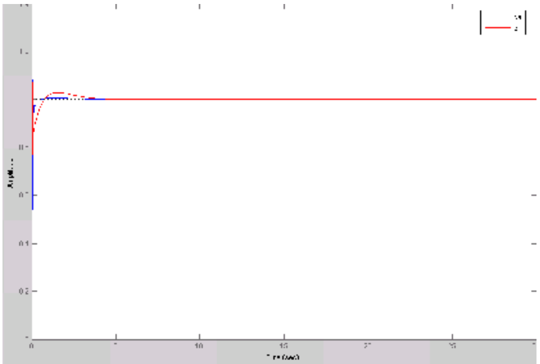

Fig 6: comparison of GA and ZN technique.

Table 5: Comparison of results.

Tuning method	Rise time	Maximum overshot	Settling time
Ziegler Nichols	0.18sec	1.08	2.41 sec
Genetic algorithm	0.161sec	1.01	0.7 sec

VIII. CONCLUSON

In this paper compare two kind of tuning techniques to control the position of dc motor. Our aim is to improve the dynamic performance of the system output like settling time, rise time and maximum overshoot. Genetic Algorithm took only a couple of seconds to solve the problem. Compared to conventionally tuned system, Genetic Algorithm tuned system has good steady state response and performance indices.

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